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TITLE: SPATIALLY BUILT WORD LIST
FOR AUTOMATIC SPEECH
RECOGNITION PROGRAM AND
METHOD FOR FORMATION
THEREOF

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1 SPATIALLY BUILT WORD LIST
2 FOR AUTOMATIC SPEECH RECOGNITION
3 PROGRAM AND METHOD FOR FORMATION THEREOF

4 BACKGROUND OF THE INVENTION

5 The present invention relates to navigation systems that support automatic speech
6 recognition for obtaining input from a user.

7 Navigation systems provide useful features, such as calculating routes to desired
8 destinations and providing guidance for following the routes. In order to provide these
9 features, navigation systems use geographic data that include information about the
10 locations of roads and intersections, estimated travel times along road segments, the
11 speed limits along roads, etc. Using these kinds of geographic data, programming
12 included in a navigation system can find an optimal (e.g., fastest or shortest) route to a
13 specified destination.

14 Although navigation systems provide many useful features, there exists room for
15 improvements. One area in which there is room for improvement relates to the use of
16 automatic speech recognition (ASR) for receiving a user's input. Some navigation
17 systems allow a user to input commands and specify destinations by speech. These
18 navigation systems include hardware, such as a microphone, and software, such as speech
19 recognition programming, to receive the user's input.

20 When a user wishes to operate a navigation system to obtain route guidance to a
21 desired destination, the user may identify the desired destination to the navigation system.
22 The user may identify this desired destination by street address, city, or in some other
23 way. In a navigation system that provides automatic speech recognition, the user may
24 speak the address, including the street name and city into the microphone of the
25 navigation system, e.g., "1420 WEST STATE STREET . . . AURORA." In a navigation
26 system that provides automatic speech recognition, algorithms operate by finding a best
27 match between the spoken words (also referred to as "utterances") and a known list of
28 words. Such algorithms may analyze a spoken utterance and compare it to each word in

1 the list. Each word may be assigned a likelihood. The word with the highest likelihood
 2 is returned as the match, if the likelihood exceeds some threshold. If no likelihood
 3 exceeds the threshold, no match is found.

4 The analysis and comparison performed by ASR functions require significant
 5 system resources. In embedded systems with limited memory, the maximum size of a
 6 word list may be about 1500 names, and perhaps smaller. However, a typical navigation
 7 database may have thousands of names, such as point of interest (POI) names (e.g.,
 8 "RICKY'S STEAK HOUSE"), place names (e.g., municipal and other government body
 9 names, such as "ILLINOIS", "CHICAGO", "ATLANTA"), and street names (e.g.,
 10 "STATE STREET", "5TH AVENUE", "ELM STREET", and so on). Thus, there are
 11 considerably more names than an ASR word list can contain.

12 One approach has been to introduce "category" words. For example, a word list,
 13 such as ("POI" "Place" "Street name"), could be provided. Then, the navigation system
 14 user would be required to first say "PLACE" before saying "MICHIGAN." The first
 15 word "PLACE" limits the next search to "places" (as opposed to "street names" or
 16 "POIs"). While this approach works well in some cases, it does not work well for other
 17 cases. For example, saying "Street name" to constrain a search within Germany,
 18 Chicago, or New York will still yield a candidate list too large for a small system to
 19 process. The same is true for POIs.

20 Another solution requires the driver to provide more word information. For
 21 example, "STREET NAME" "OAK PARK" will narrow the search to streets in "Oak
 22 Park." However, this approach also has drawbacks. For example, a driver wanting to go
 23 to "931 Lake Street" may not know whether the destination is in "Oak Park", "Chicago",
 24 or some other community. An out-of-town driver could not be expected to know the
 25 names of various suburban communities.

26 Accordingly, there is a need to improve how a navigation system handles speech
 27 recognition.

28

1 SUMMARY OF THE INVENTION

2 To address these and other objectives, the present invention comprises a program
3 and method for building a word list for use by an automatic speech recognition program
4 in a vehicle navigation system. The automatic speech recognition program matches
5 spoken words that describe geographic features, such as places, street names and points
6 of interest, to entries in the word list. The word list contains a limited number of entries.
7 In order to increase the likelihood that a word spoken by a user of the navigation system
8 is included among the limited number of entries contained in the word list, the word list
9 contains entries that correspond to the named geographic features closest to a current
10 position of the vehicle. As the vehicle travels through a geographic area, the word list is
11 rebuilt to include entries that correspond to the named geographic features closest to the
12 new current vehicle position.

13 According to another embodiment, a portion of the word list is reserved for a
14 limited number of entries that correspond to named geographic features that may not be
15 close to the current vehicle position but which are included because of their popularity or
16 importance.

17

18 BRIEF DESCRIPTION OF THE DRAWINGS

19 Figure 1 is a block diagram illustrating components of a navigation system.

20 Figure 2 is a block diagram of some of the component software applications
21 included in the navigation system of Figure 1.

22 Figure 3 is a flow chart showing operation of the automatic speech recognition
23 word list builder program shown in Figure 2.

24 Figure 4 is a block diagram showing components of the active word list shown in
25 Figures 2 and 3.

26 Figure 5 is a block diagram showing organization of portions of the geographic
27 database used by the navigation system in Figure 1.

28 Figure 6 is a block diagram showing organization of a spatial index for
29 geographic feature names included in the geographic database of Figure 5.

30 Figure 7 is a map of a geographic area and is used to illustrate operation of the
31 automatic speech recognition word list builder program shown in Figure 2.

Figure 8 is a block diagram showing organization of an alternative embodiment for the spatial index for geographic feature names included in the geographic database of Figure 5.

Figures 9A-9D illustrate alternative embodiments for determining the area corresponding to which name pronunciation data are selected for the active word list.

Figure 10 illustrates an alternative embodiment for determining the threshold boundary used for determining when to rebuild the active word list.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

I. EXEMPLARY NAVIGATION SYSTEM PLATFORM

A. Overview

Referring to Figure 1, there is a diagram illustrating an exemplary embodiment of a navigation system 110. In the embodiment shown in Figure 1, the navigation system 110 is located in a vehicle 111, such as an automobile, truck, or bus. The navigation system 110 is a combination of hardware and software components. The hardware components of the navigation system 110 may include a processor 112, memory 120, and so on. In the embodiment of Figure 1, the navigation system 110 also includes a positioning system 124 that determines the position of the vehicle 111 in which it is installed. The positioning system 124 may include sensors 125 or other components that sense the speed, orientation, direction, angular acceleration, and so on, of the vehicle 111. The positioning system 124 may also include a GPS system.

The navigation system 110 also includes a user interface 131. The user interface 131 includes appropriate means 127 for receiving input from an end user of the navigation system. The input receiving means 127 may include a keyboard, keypad, or other type of input panel 127(P), a microphone 127(M), as well as other means for accepting end-user input, such as voice recognition software, and so on, through which the end user may request navigation information and services. The user interface 131 also includes appropriate means 129 for providing information back to the end user. The information providing means 129 may include a display 129(D) and speakers 129(S)

1 (including speech synthesis hardware and software) through which the end user can be
2 provided with information and services from the navigation system 110.

3 The navigation system 110 optionally includes a communications system 128.
4 The communications system 128, if present, includes the appropriate hardware and
5 software to send and receive data messages wirelessly. The communications system 128
6 may be implemented using any available technology for transmitting messages. The
7 communications systems 128 is operatively coupled to other components of the
8 navigation system 110 so that messages can be sent from and received by the navigation
9 system.

10 All of the components described above may be conventional (or other than
11 conventional) and the manufacture and use of these components are known to those of
12 skill in the art.

13 14 B. The geographic database

15 In order to provide navigation features to the end user, the navigation system 110
16 uses geographic data 140. The geographic data 140 include information about one or
17 more geographic regions or coverage areas. The geographic data 140 may be stored in
18 the vehicle 111 or alternatively, the geographic data 140 may be stored remotely and
19 made available to the navigation system 110 in the vehicle 111 through the wireless
20 communication system 128 which may be part of the navigation system 110. In another
21 alternative, a portion of the geographic data 140 may be stored in the vehicle 111 and a
22 portion of the geographic data 140 may be stored in a remote location and made available
23 to the navigation system 110 in the vehicle 111 over the wireless communication system
24 128 from the remote location.

25 In the embodiment shown in Figure 1, some or all of the geographic data 140 are
26 stored on a medium 132 which is located in the vehicle 111. Accordingly, the navigation
27 system 110 includes a drive 114 (or other suitable peripheral device) into which the
28 medium 132 can be installed and accessed. In one embodiment, the storage medium 132
29 is a CD-ROM disk. In another alternative embodiment, the storage medium 132 may be
30 a PCMCIA card in which case the drive 114 would be substituted with a PCMCIA slot.
31 Various other storage media may be used, including fixed or hard disks, DVD disks or

1 other currently available storage media, as well as storage media that may be developed
2 in the future.

3 The geographic data 140 include data specifying the positions of the roads in the
4 covered geographic region(s). The geographic data 140 also include data relating to the
5 roads, such as restrictions on directions of travel along the roads (e.g., one-way streets),
6 street addresses along the roads, street names, speed limits along the roads, turn
7 restrictions at intersections, and so on. The geographic data 140 may also include
8 information about points of interest in the geographic area, such as hotels, restaurants,
9 museums, stadiums, offices, automobile dealerships, auto repair shops, etc. The
10 geographic data 140 may also include information about places, such as cities, towns, or
11 other communities. The geographic data 140 may include other kinds of data about the
12 geographic area.

13 The geographic data 140 may take a variety of different forms. In one
14 embodiment, the geographic data 140 are in the form of one or more computer-readable
15 data files or databases 141. Methods for forming and organizing a geographic database
16 are disclosed in U.S. Pat. Nos. 5,953,722, 5,974,419 and 5,968,109, the disclosures of
17 which are incorporated herein by reference. In one embodiment, the geographic database
18 141 contains a plurality of road segment data records. Each road segment data record
19 represents a portion (or segment) of a navigable road in the geographic region. In one
20 type of geographic database, there is at least one database entry (also referred to as
21 "entity" or "record") for each represented road segment in a geographic region. A road
22 segment data record may include a segment ID by which the record can be identified in
23 the geographic database. Data attributes are associated with each road segment data
24 record to describe features or characteristics of the represented road segment. The road
25 segment data record may include attributes representing the speed limit along the road (or
26 a speed limit range), the type of road (e.g., controlled access, ramp, bridge, tunnel, toll
27 road, ferry, and so on), a functional rank, a permitted direction of travel, an address
28 range, a name, a highway designation of the road of which the road segment is a part, and
29 so on. The various attributes associated with a road segment may be included in a single
30 road segment record, or may be included in more than one type of record that are cross-
31 referenced to each other.

1 In one embodiment, the geographic data are provided by Navigation Technologies
2 Corporation of Rosemont, Illinois. However, it is understood that the inventive concepts
3 disclosed herein are not restricted to any particular source of data.

4
5 C. The applications in the navigation system.

6 As shown in Figure 1, the navigation system 110 includes or uses software
7 programming 228. The software programming 228 includes the programs and
8 applications that provide for the functions and/or features performed by the navigation
9 system 110. The software programming 228 uses the geographic data 140 in conjunction
10 with input from the end user via the user interface 131, and possibly in conjunction with
11 outputs from the positioning system 124, to provide various navigation-related features
12 and/or functions.

13 The software programming 228 may be stored in a non-volatile storage medium
14 227 in the navigation system 110. Alternatively, the software programming 228 and the
15 geographic data 140 may be stored together on a single storage device or medium.
16 Alternatively, the software programming 228 may be located at a remote location and
17 may be provided to or accessed by the navigation system 110 over the communications
18 system 128.

19 In one embodiment, the software programming 228 is written in the
20 C programming language although in alternative embodiments other programming
21 languages may be used, such as C++, Java, Visual Basic, and so on.

22 The software programming 228 may be formed of separate component
23 applications 229 (also referred to as programs, subprograms, routines, or tools). The
24 component applications 229 work together through defined programming interfaces.
25 Figure 2 shows a block diagram illustrating some of the component applications 229 for
26 one embodiment of the software programming 228 included in the navigation system 110
27 of Figure 1. In addition to the component applications 229 shown in Figure 2, the
28 software programming 228 may include other component sub-routines or programs, such
29 as an operating system 230 and a data access interface layer 232 as well as other
30 programs. (An embodiment of a data access interface layer is described in U.S. Pat. No.
31 6,047,280, the entire disclosure of which is incorporated by reference.)

1 In Figure 2, the applications 229 include an application manager 240. The
2 application manager 240 is a program or routine that provides for overall management of
3 the functions of the navigation system 110. The application manager 240 may also
4 include support for and interfaces with the navigation system hardware, such as the
5 positioning system 124 and the user interface 131. The software programming 229
6 includes user interface functions to interface with the user interface hardware 131. These
7 user interface functions may provide for presenting a menu to the end user on the screen
8 display 129(D) of the user interface hardware 131, accepting inputs from the end user via
9 the input devices 127 of the user interface hardware 131, displaying results to the end
10 user on the screen display 129(D) of the user interface hardware 131, and so on.

11 The applications 229 include sub-programs or routines that interface with the
12 application manager 240 and that provide for specific navigation-related features or
13 functions to be performed by the navigation system. These sub-programs include a route
14 calculation application 250, a route guidance application 252, a map display application
15 254, a vehicle positioning application 256 and a geo-coding application 258. The
16 software programming 228 may include other navigation applications in addition to
17 these.

18 Methods for route calculation are disclosed in Ser. No. 09/047,698, filed
19 March 25, 1998; methods for providing route guidance are disclosed in Ser. No.
20 08/893,201, filed July 15, 1997 and Ser. No. 09/196,279, filed November 19, 1998;
21 methods for providing vehicle positioning are disclosed in Ser. No. 09/276,377, filed
22 March 25, 1999; and methods for providing map display are disclosed in U.S. Pat. No.
23 6,163,749 and U.S. Pat. No. 6,092,076. The disclosures of these six patents or
24 applications are incorporated by reference herein. The methods disclosed in these patents
25 or applications represent only some of the ways that these functions can be provided and
26 the subject matter claimed herein is not limited to any particular method. Any suitable
27 method now known or developed in the future may be employed.

28
29 D. The automatic speech recognition program.

30 The applications 229 also include an automatic speech recognition program 260.
31 The automatic speech recognition program 260 operates under the control of the manager

1 application 240. The automatic speech recognition program 260 receives a data
2 representation of spoken words or utterances. (Capture of spoken words or utterances
3 and conversion of the spoken words and utterances into data representations are
4 performed by another component in the navigation system or another system, according
5 to any process or equipment known to those of skill in the art or developed in the future.)
6 The automatic speech recognition program 260 matches the data representation of spoken
7 words to one or more entries in an active word list (or dictionary) 262. The automatic
8 speech recognition program 260 uses any of several known algorithms for performing
9 this matching.

10 The active word list 262 used by the automatic speech recognition program 260
11 contains word pronunciation data 264. The word pronunciation data 264 in the active
12 word list 262 correspond to a plurality of distinct words. The entries in the active word
13 list 262 correspond to the names of points of interest, places, street names, as well as
14 commands, and so on.

15 In the embodiment of Figure 2, there are a limited number of distinct words or
16 entries in the active word list 262. For example, the number of distinct words may be
17 approximately 1000, 1500, 2000, or some other finite number. The number of distinct
18 words contained in the active word list is constrained by several factors. One factor
19 relates to the amount of memory available to the navigation system for performing
20 automatic speech recognition. The amount of available memory affects the number of
21 different words that can be distinguished at a time by automatic speech recognition
22 algorithms. Some automatic speech recognition algorithms are limited to distinguishing
23 only a limited number of different words, such as 1000, 1500, or 2000.

24 In general, the number of different names for geographic features that are
25 represented in the geographic database 141 far exceeds the number of distinct words that
26 can be contained in the active word list. Thus, the number of distinct words that the
27 active word list 262 can hold represents only a portion, and in some cases a relatively
28 small portion, of all the names of all the geographic features that are represented in the
29 geographic database 141.

30

II. THE ASR WORD LIST BUILDER PROGRAM

Referring to Figure 2, included among the applications 229 in the navigation system 110 is an ASR word list builder program 300. The ASR word list builder program 300 operates during runtime of the navigation system 110. The ASR word list builder program 300 builds and re-builds, as necessary, the active word list 262 used by the automatic speech recognition program 260. The ASR word list builder program 300 includes two components or functions. The ASR word list builder program 300 includes a threshold monitor routine 302 and a re-builder routine 304. Figure 3 shows steps performed by these components of the ASR word list builder program 300.

Referring to Figure 3, the threshold monitor routine 300 begins when the navigation system 110 is started or when the threshold monitor routine 300 is re-initialized (Step 400). The threshold monitor routine 302 obtains data 402 indicating the current vehicle position (Step 404). These data 402 may be obtained from the vehicle positioning application 256 or alternatively, the data 402 indicating the current vehicle position may be obtained from the positioning system 124. The data 402 indicating the current vehicle position may include the geographic coordinates of the vehicle position or alternatively, the data 402 indicating the current vehicle position may be referenced to the map data contained in the geographic database 141 that represent the road network.

Using the data 402 indicating the current vehicle position, the threshold monitor routine 302 determines the distance, D , between the current vehicle position and a position 410 associated with the active word list 262, if present (Step 412). If the distance, D , from the current vehicle position to the position 410 associated with the active word list does not exceed a threshold, T , the threshold monitor routine 302 loops back to Step 404 and obtains a new current vehicle position (Step 416). Then, the threshold monitor routine 302 continues, i.e., proceeding to the step in which the distance between the new current vehicle position and the position 410 associated with the active word list 262 is determined, and so on.

At Step 416, if the distance, D , from the current vehicle position to the position 410 associated with the active word list exceeds the threshold, T , the threshold monitor routine 302 calls the word list re-builder routine 304. When the re-builder routine 304 is called by the threshold monitor routine 302, it rebuilds the active word list 262. To

1 perform this process, the re-builder routine 304 obtains the data 402 indicating the current
2 vehicle position. These data 402 indicating the current vehicle position may be obtained
3 from the vehicle positioning application 256, the positioning system 124, or the threshold
4 monitor routine 302. When rebuilding the active word list 262, the re-builder routine 304
5 obtains from the geographic database 141 the name pronunciation data associated with
6 named represented geographic features. The named represented geographic features for
7 which name pronunciation data are obtained may include streets, places, and points of
8 interest.

9 As mentioned above, the active word list 262 has a limited size. For example, the
10 active word list 262 may be limited to approximately 1500 entries representing
11 approximately 1500 different named geographic features. These 1500 geographic
12 features may represent only a small portion of all the named geographic features
13 represented in the geographic database 141 (especially if the geographic database
14 represents a relatively large coverage area, such as the entire United States).
15 Accordingly, it is preferred that the active word list 262 contain data for those named
16 geographic features that are most likely to be needed. Therefore, when the re-builder
17 routine 304 obtains name pronunciation data from the geographic database 141, it obtains
18 the name pronunciation data associated with those represented features that are closest to
19 the current vehicle position.

20 It is recognized that not all likely destinations are necessarily close to the current
21 vehicle position. Instead, some named geographic features are possible likely
22 destinations because of their popularity or importance even though they may be far away
23 from the current vehicle position. Therefore, although the active word list 262 may have
24 room for a specific number of entries, e.g., 1500, the re-builder routine 304 does not
25 obtain from the geographic database name pronunciation data for all the possible entries
26 in the active word list 262. Instead, a portion of the active word list 262 is reserved for
27 name pronunciation data associated with represented named geographic features that are
28 not close to the current vehicle position, but that are possible likely destinations because
29 of their popularity or importance.

30 Figure 4 is a diagram that illustrates one embodiment of the organization of the
31 active word list 262 that includes entries for named geographic features that are close to

1 the vehicle position as well as entries for named geographic features that are not
 2 necessarily close to the vehicle position, but that are likely destinations because of their
 3 importance or popularity. In Figure 4, the active word list 262 is shown to have a
 4 plurality of entries 450. Each entry represents the phonetic pronunciation of a name of a
 5 particular represented geographic feature. The active word list 262 maintains two types
 6 of entries: reserved entries 454 and replaceable entries 460. The reserved entries 454 in
 7 the active word list 262 contain the name pronunciation data for represented features that
 8 are possible likely destinations, even though they are relatively far away. For example,
 9 the reserved entries 454 in the active word list 262 contain name pronunciation data for
 10 common popular destinations, such as "NEW YORK", "DISNEYLAND", "LAS
 11 VEGAS", "GRAND CANYON", "BROADWAY", "5TH AVENUE", and so on. These
 12 geographic features, even though they may be far away from the current position of the
 13 vehicle, are often visited by people or are well known, and therefore are likely
 14 destinations. Thus, the name pronunciation data for these features are included in the
 15 active word list 262.

16 In one embodiment, the reserved entries on the active word list are static.
 17 However, in another embodiment, the reserved entries on the active word list are
 18 dynamic and may be updated on a regular basis or each time the system is run. The
 19 entries on the reserved list may also be weighted.

20 The reserved entries may also contain command and control words, such as
 21 "SCROLL MAP", "RECALCULATE", "CANCEL", etc.

22 The replaceable entries 460 in the active word list 262 in Figure 4 also contain
 23 name pronunciation data for represented features. However, the replaceable entries 460
 24 in the active word list 262 are the names of geographic features that are closest to the
 25 current vehicle position. (Note that in Figure 4, the reserved entries 454 are shown as
 26 being separate from the replaceable entries 460. In the active word list 262, the reserved
 27 entries 454 and the replaceable entries 460 may not necessarily be organized as separate
 28 collections of entries, but instead may be organized in a suitable manner for use by the
 29 automatic speech recognition program 260.)

30 Referring back to Figure 3, when the re-builder routine 304 rebuilds the active
 31 word list 262, it obtains name pronunciation data from the geographic database 141

1 (Step 480). As mentioned above, the active word list 262 has a limited size and, in a
2 present embodiment, some of the entries in the active word list 262 are reserved and
3 therefore not replaceable. Thus, in the present embodiment, there are limited number of
4 entries (e.g., "X") that are available in the active word list 262 for replacement by the
5 re-builder routine 304. Accordingly, the re-builder routine 304 uses the data 402
6 indicating the current vehicle position to obtain name pronunciation data from the
7 geographic database 141 for only those geographic features that are closest to the current
8 vehicle position. More specifically, the re-builder routine 304 obtains name
9 pronunciation data for the X number of closest named geographic features. In the
10 embodiment of Figure 4, X is the remainder of available entries in the active word list
11 262 after subtracting the number of reserved entries from the total number of entries
12 available in the active word list. (In one embodiment, the number of entries available for
13 replacement, i.e., X , is approximately 1000, but alternatively, the number of entries
14 available for replacement may be any other number, consistent with the hardware and
15 software resources of the navigation system. In alternative embodiments, the number
16 may be configurable.)

17 In order to facilitate operation of the re-builder routine 304, the geographic
18 database 141 is organized in a manner that facilitates finding the name pronunciation data
19 for geographic features spatially. Figures 5 and 6 illustrate an arrangement in which the
20 geographic database 141 can be organized in order to facilitate identifying name
21 pronunciation data for geographic locations based upon the proximity of the geographic
22 data from a selectable position. In Figure 5, the geographic database 141 is shown as
23 being organized into different types or sets of data 490. These types or sets 490 include
24 routing 492, cartographic 494, points of interest 496, names 498 and pronunciation 500.
25 The geographic database 141 may include other types of data in addition to these. (These
26 types of data may be provided as actual separate physical collections or alternatively,
27 these types of data may be intermingled or interleaved with each other.) These different
28 kinds of data 490 may represent the same geographic features. However, each of these
29 different types of data contains different attributes of these features. As an example, the
30 routing type of data 492 includes those attributes about road segments that relate to
31 calculation of routes between locations. The cartographic data 494 includes those

1 attributes about road segments, as well as other geographic features, that are used to
 2 display the features as a graphical map. The name data 498 contains the names (e.g., in
 3 text) of the navigable features, such as roads. The name data 498 may also include the
 4 names of other types of geographic features, such as places (e.g., cities, states,
 5 neighborhoods), points of interests, and other types of geographic features (e.g., rivers,
 6 lakes, mountain ranges). The pronunciation data 500 includes phonetic representations
 7 for each of the different names included in the name data 498.

8 Each of the different navigation system applications (e.g., route calculation 252,
 9 route guidance 254, map display 256, automatic speech recognition 260, and so on, in
 10 Figure 2) uses one or more of the different types 490 of data when operating. In order to
 11 enable navigation system applications to use these different types of data, the geographic
 12 database 141 includes one or more indexes 502 that relate these different types of data to
 13 each other.

14 As shown in Figure 6, to facilitate operation of the re-builder routine 304, the
 15 geographic database 141 includes a spatial name index 510. The spatial name index 510
 16 is one of the indexes 502 in the geographic database 141 that relate the different types of
 17 data to each other. The spatial name index 510 supports decreasing density radial name
 18 searches. The spatial name index 510 can be used to order names by proximity to a
 19 specified location. For example, in the spatial name index 510, the references to the
 20 names could be Peano-key order, or alternatively, other suitable spatial ordering may be
 21 used. In addition, the spatial name index 510 can be used to order names falling along a
 22 vector or to order names located between two points.

23 Referring again to Figure 3, using the data 402 indicating the current vehicle
 24 position, the re-builder routine 304 obtains from the geographic database 131 the
 25 pronunciation data for the *X* number of named geographic features that are closest to the
 26 current vehicle position (Step 480). The pronunciation data that are obtained from the
 27 geographic database are stored in the active word list 262 (Step 582). The pronunciation
 28 data obtained from the geographic database 141 replace the replaceable entries 460
 29 contained in the active word list 262. The re-builder routine 304 does not replace the
 30 reserved entries 454. After replacing the replaceable entries 460 in the active word list
 31 262 with new pronunciation data, the active word list 262 contains the pronunciation

1 data, which had been newly obtained from the geographic database 141, as a new set of
2 replaceable entries 460. The active word list 262 also contains the same reserved entries
3 454 as before.

4 When the re-builder routine builds the new active word list 262, it may store some
5 or all of the new active word list in a non-volatile, re-writable memory in the navigation
6 system. Alternatively, when the re-builder routine builds the new active word list, it may
7 maintain some or all of the new active word list in RAM.

8 When the re-builder routine 304 rebuilds the active word list 262 by replacing the
9 replaceable entries 460 with new name pronunciation data corresponding to the X closest
10 named geographic features, the re-builder routine 304 also updates the data 410
11 indicating the location associated with the active word list. The data 410 may be the
12 position of the vehicle when the active word list was re-built. The re-builder routine 304
13 stores the data 410 indicating a location associated with the active word list 262 so that
14 the active word list can be rebuilt as necessary to include pronunciation data for those
15 named geographic features that are most closely located to the vehicle's position as the
16 vehicle travels in a geographic area. The data 410 may be stored with the active word list
17 262, either in the non-volatile, re-writable data storage or in RAM. The data 410
18 indicating the location associated with the build of the active word list 262 may be stored
19 with the active word list, e.g., as part a file header.

20 As stated above, as the vehicle travels away from the location at which the active
21 word list was built (or re-built), the threshold monitor routine 302 monitors how far the
22 vehicle has traveled from the location at which the active word list was built. As stated
23 above, when this distance exceeds a threshold distance, T , the threshold monitor routine
24 302 calls the re-builder routine when the distance exceeds the threshold.

25 The threshold distance, T , may be fixed or configurable. Alternatively, the
26 threshold distance, T , may be calculated as a function of other parameters, such as vehicle
27 speed, administrative boundary, direction, etc. According to another alternative shown in
28 Figure 3, the threshold distance, T , is related to the density of the geographic features
29 around the location at which the active word list was built (Step 584).

30 The reason why the threshold distance, T , is related to the density of the
31 geographic features around the location at which the active word list was built is that

1 some parts of a geographic region are more densely-featured than other parts. For
 2 example, an urban area contains more streets and businesses than a rural area. However,
 3 as previously indicated, the number of replaceable entries 460 in the active word list is
 4 limited to some fixed (or configurable) number, i.e., X . As a result, when the re-builder
 5 routine 304 obtains the pronunciation data for the X number of closest named geographic
 6 features, the size of the geographic area corresponding to these X number of names is
 7 relatively smaller in densely-featured areas, such as cities, and relatively larger in
 8 sparsely-featured areas, such as rural areas and suburbs. Thus, when the vehicle is
 9 traveling across a densely-featured area, the need to re-build the active word list arises
 10 after traveling less distance than when the vehicle is traveling across a sparsely-featured
 11 area.

12 In order to account for the need to re-build the active word list more frequently
 13 (with respect to distance traveled) when traveling across densely-featured areas, the
 14 threshold distance T used to determine when to re-build the active word list can be made
 15 a function of the density of the named features around the location at which the active
 16 word list is re-built. One way this can be accomplished is to determine the outer
 17 boundary of the area around the location at which the active word list is re-built that
 18 encompasses the X closest named geographic features. The threshold distance, T , is then
 19 determined as a fraction (e.g., $1/2$, $1/3$, etc.) of the distance from the location at which the
 20 active word list was re-built to the outer boundary. Thus, as long as the vehicle travels
 21 relatively close to the location at which the active word list was re-built, there is no need
 22 to re-build the active word list. However, as the vehicle approaches the boundary, the
 23 need to re-build the active word list arises. Therefore, by relating the size of the re-build
 24 threshold T to the size of the area covered by the names in the active word list, the active
 25 word list is re-built when appropriate in order to maintain those names of the closest, and
 26 therefore most likely, geographic features.

27 After the re-build routine 304 determines the new re-build threshold distance, T ,
 28 the re-build routine 304 stores the data indicating the new threshold distance. The data
 29 indicating the new threshold distance, T , may be stored with the active word list, e.g., as
 30 part the file header, or elsewhere in a memory or data storage of the navigation system.

1 After the re-build routine 304 has stored these data, the re-build routine 304 returns to the
2 threshold monitor routine 302 (Step 586).

3 The name pronunciation data in the active word list 262 are now available for use
4 by the automatic speech recognition program (260 in Figure 2). The threshold monitor
5 routine 302 then continues to operate by obtaining a new vehicle position (Step 404 in
6 Figure 3) and determining the distance from the new vehicle position to the newly
7 determined position 410 associated with the re-built active word list (Step 412).

8

9 Example

10 Referring to Figure 7, the vehicle 111 in which the navigation system 110 is
11 installed is located at a position 600 in a geographic area 606. When the vehicle 111 is at
12 the position 600, the navigation system 110 is started. The threshold monitor routine 302
13 (in Figure 3) starts, obtains the current position of the vehicle 111 from the vehicle
14 positioning application 256 and determines the distance from the current vehicle position
15 to the position associated with the active word list. In this case, there is no active word
16 list since the vehicle has just been turned on. Therefore, the threshold monitor routine
17 302 calls the re-builder routine 304.

18 The re-builder routine 304 (in Figure 3) obtains from the geographic database 141
19 pronunciation data for the geographic features located closest to the current vehicle
20 position 600. The re-builder routine 304 adds these pronunciation data to the
21 pronunciation data for the reserved entries to form a new build of the active word list
22 262. When the re-builder routine 304 obtains name pronunciation data from the
23 geographic database to rebuild the active word list, it obtains the name pronunciation data
24 for those named geographic features that are located closest to the current vehicle
25 position 600. Taking into account the limited size of the active word list and the number
26 of reserved entries, the pronunciation data obtained from the geographic database for the
27 named geographic features located closest to the current vehicle position extend out to
28 the boundary indicated by the line 612. Thus, the active word list contains pronunciation
29 data for all the named geographic features encompassed within the boundary 612. (In
30 addition, as indicated above, the active word list contains pronunciation data for certain

1 named geographic features that may be located outside the boundary 612, but that are
2 likely destinations by reason of being popular or important destinations.)

3 When the re-builder routine 304 rebuilds the active word list, it stores data
4 indicating the position (i.e., "600") associated with the build. The re-builder routine 304
5 also stores data indicating the threshold distance (i.e., T) which may be related to the
6 distance from the position 600 to the boundary 612. When the active word list has been
7 re-built, the automatic speech recognition program 260 (in Figure 2) can use the data
8 contained therein for speech recognition purposes.

9 Continuing to refer to Figure 7, the vehicle 111 then travels to the position 620.
10 As the vehicle is traveling to the position 620, the threshold monitor routine 302 obtains
11 the current vehicle position, determines the distance from the current vehicle position to
12 the position associated with the active word list, and compares the distance to the
13 threshold distance. When the vehicle is at the position 620, the distance from the current
14 vehicle position 620 to the position associated with the active word list is less than the
15 threshold distance. Therefore, the active word list that was built at the position 600
16 continues to be used by the automatic speech recognition program.

17 Continuing to refer to Figure 7, the vehicle 111 then travels to the position 630.
18 When the vehicle 111 is at the position 630, the distance from the current vehicle position
19 620 to the position associated with the active word list exceeds the threshold distance.
20 Therefore, the active word list that was built at the position 600 is no longer valid and the
21 re-builder routine 304 is called to re-build the active word list 262.

22 23 III. ALTERNATIVE EMBODIMENTS

24 Some navigation systems are standalone devices. In a standalone navigation
25 system, all the hardware, software and data are present locally in the system. Another
26 kind of navigation system has some or all of the software and/or data (including
27 corresponding hardware) located remotely. In this type of navigation system, the
28 functions and/or data that are located remotely are made available to the components of
29 the navigation system that are located locally over a communications medium, which
30 may be a wireless medium. The disclosed concepts relating to building of an active word
31 list are applicable to standalone navigation systems, navigation systems that rely on

1 remotely located data and/or software, and well as hybrid systems that combine locally
2 stored data and/or software with remotely stored data/or software.

3 Navigation system may be dedicated devices. Navigation systems may be
4 installed in vehicles. These in-vehicle navigation systems include systems installed by
5 the automobile manufacture as well as after-market installed systems. Navigation
6 functions can also be provided by general purpose computing devices, such as personal
7 computers (including laptop computers) and personal digital assistants. The disclosed
8 concepts relating to building of an active word list for speech recognition are applicable
9 to dedicated systems and systems implemented on general purpose devices.

10 In one of the embodiments described above, the active word list was described as
11 including two types of entries: reserved entries and replaceable entries. In an alternative
12 embodiment, the active word list can contain more than two types of entries. As an
13 example, the active word list may contain three or more different kinds of entries. In one
14 alternative embodiment, a third type of entry combines aspects of the replaceable entry
15 and the reserved entry. According to this embodiment, the third type of entry
16 corresponds to names of geographic places that are beyond the immediate threshold of
17 closest geographic features, but still are related to the vehicle position. As an example,
18 "WACKER DRIVE" is the name of a street in downtown Chicago. "WACKER DRIVE"
19 is a likely destination for a navigation system user in the Chicago metropolitan area.
20 However, "WACKER DRIVE" is not a likely destination for navigation system users
21 outside the Chicago metropolitan area. Accordingly, the pronunciation data for
22 "WACKER DRIVE" is not a reserved entry because it is not a likely destination for
23 navigation system users outside Chicago. However, because the Chicago metropolitan
24 area has a large number of named geographic features, there are places in the Chicago
25 metropolitan area where the word list builder program operating in a navigation system
26 would use all the available replaceable entries in a active word list, but not include
27 "WACKER DRIVE" because it would not be among the X number of closest named
28 geographic features. According to this alternative embodiment, the third category of
29 entries in the active word list would include pronunciation data for these types of
30 geographic features. To implement this, a second distance threshold (e.g., $T(2)$) can be
31 used for selection of these named geographic features.

1 In another alternative embodiment, instead of forming the active word list with
2 reserved entries and replaceable entries, all the entries can be replaceable. According to
3 this embodiment, included with the name data in the geographic database is an attribute
4 field that is used to indicate the importance of the represented named geographic feature.
5 In one embodiment, the importance field can include a number from 0-7. Residential
6 street names and other local features, such as non-chain restaurants, are assigned an
7 importance rating of 0. Business streets are assigned an importance rating of 2. City
8 names, streets and points of interest that are important across a metropolitan area are
9 assigned a rating of 5. Streets and destinations that are important across a metropolitan
10 area are assigned a rating of 5. Streets and destinations that are important nationally are
11 assigned a rating of 7. Figure 8 is an example of the components in an alternative
12 embodiment of the geographic database 141 that includes an importance attribute
13 associated with named geographic features. According to this embodiment, when the re-
14 build routine is called to re-build the active word list, all the entries are replaced. When
15 determining which entries to include when re-building the active word list, the re-builder
16 routine uses a plurality of factors that combines the distance of the named geographic
17 feature from the current position of the vehicle and the importance of the named
18 geographic feature. With this embodiment, by proper scaling of the factors, a geographic
19 feature having an importance rating of 7 will always be included in the active word list.

20 In the above embodiments, the active word list was described as being used by the
21 automatic speech recognition program. In an alternative embodiment, the active word list
22 may also be used for speech generation (synthesis) purposes.

23 In some of the embodiments disclosed above, the active word list was described
24 as being built to contain the pronunciation data for the geographic features closest to the
25 current vehicle position. In alternative embodiments, the geographic area corresponding
26 to the pronunciation data contained in the active word list can be offset from the current
27 position of the vehicle so that the geographic features represented by the pronunciation
28 data are not necessarily the closest features to the current vehicle position. For example,
29 the geographic area corresponding to the pronunciation data contained in the active word
30 list can be offset in the direction of travel from the current position of the vehicle.

31 According to another alternative, the geographic area corresponding to the pronunciation

1 data contained in the active word list can correspond to an administrative area, such as a
2 city, county or state, in which the vehicle is located. According to another alternative, the
3 geographic area corresponding to the pronunciation data contained in the active word list
4 can be located along a route upon which the vehicle is traveling. Some of these
5 alternatives are illustrated in Figures 9A-9D.

6 In some of the embodiments disclosed above, the threshold boundary was related
7 to the boundary of the area corresponding to the named geographic features contained in
8 the active word list. In an alternative embodiment, determination of the threshold
9 boundary can take other factors into account, such as vehicle speed, administrative
10 boundaries, direction, etc. Figure 10 shows an example of how the threshold boundary
11 can be calculated taking into account the direction of travel of the vehicle.

12 13 IV. ADVANTAGES

14 Several advantages follow from the disclosed embodiments. For example, one
15 advantage is improved performance (as measured by reduced processing time and
16 reduced memory requirements) of ASR algorithms operating in an in-vehicle
17 environment.

18
19 It is intended that the foregoing detailed description be regarded as illustrative
20 rather than limiting and that it is understood that the following claims including all
21 equivalents are intended to define the scope of the invention.